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From Bean to Brew: Exploring the Formation of Process Contaminants in Coffee Roasting

Christopher D. Martin* **and Daniel Redwood**

Department of Agricultural, Food, Environmental and Animal Sciences, University of Udine, Udine, Italy

Abstract

This manual is an updated version of laboratory manual for Food Analysis. It has been compiled to fill in the gap in the existing old manual used in the laboratory of the Food Science and Postharvest Technology Department. The old version was a fragmented piece of protocols for each parameter and creates difficulty for a reader who needs to understand the method principle of each parameter to be measured in detail. The scope of this manual has taken into account the details of proximate analysis methods (moisture content, crude protein, crude fat, crude fiber, and ash content and total carbohydrate); bioactive determination methods (polyphenol, total flavonoid, ascorbic acid, and beta-carotene) and method of total antioxidant capacity determination. Furthermore, this updated version of the manual covers the basic principles and analytical procedures applied in the analysis of proximate, bioactive components and antioxidant capacity as applied to food biomaterials. A great effort has been made by the contributor of this document to make it very easy so as to make it a user friendly type manual for the readers and users.

Keywords: Coffee roasting • Process contaminants • Formation mechanisms • Health implications

Introduction

Coffee is one of the most widely consumed beverages globally, appreciated for its rich flavors, enticing aromas, and stimulating properties. The process of roasting, a critical step in coffee production, not only imparts desirable sensory attributes but also contributes to the formation of process contaminants. These contaminants arise as a result of complex chemical reactions occurring during roasting, and their presence can have significant implications for both the safety and quality of the final coffee product. Coffee roasting involves subjecting green coffee beans to elevated temperatures, leading to a series of intricate transformations. These reactions encompass Maillard reactions, Strecker degradation, lipid oxidation, and the breakdown of chlorogenic acids. While these processes contribute to the development of the unique flavor and aroma profiles associated with roasted coffee, they can also generate a variety of compounds that may pose potential health risks if present in excessive amounts.

Understanding the formation mechanisms of process contaminants during coffee roasting is crucial for several reasons. Firstly, it enables coffee producers to identify the factors that influence their generation, such as roasting parameters (e.g., temperature, time, and moisture content), thus offering opportunities for mitigation strategies. Secondly, it allows for the development of analytical techniques to detect and quantify these contaminants accurately, facilitating quality control measures and compliance with regulatory standards. Moreover, comprehending the health implications of these process contaminants is essential to ensure the safety of coffee consumption and protect consumer well-being.

This comprehensive review aims to explore and characterize the formation of process contaminants during coffee roasting. It will delve into the intricate chemical reactions that occur, discuss the identification techniques employed, examine the common types of contaminants found in roasted coffee, and evaluate their potential health risks. Furthermore, the review will highlight mitigation strategies that coffee producers can adopt to minimize the formation of process contaminants and ensure the production of safe and high-quality roasted coffee. By enhancing our understanding of these contaminants, we can work towards optimizing coffee roasting processes and promoting consumer confidence in the coffee industry [1,2].

Literature Review

Coffee roasting is a complex process that involves the application of heat to green coffee beans, resulting in the development of desirable flavors and aromas. However, this thermal transformation also leads to the formation of various process contaminants, which can have implications for the safety and quality of the final coffee product. Understanding the formation mechanisms of these contaminants is essential for implementing mitigation strategies and ensuring the production of safe and high-quality roasted coffee. This section presents a review and literature overview of the formation mechanisms of process contaminants during coffee roasting [3].

Maillard reactions

One of the key reactions occurring during coffee roasting is the Maillard reaction, which involves the reaction between reducing sugars and amino acids. This non-enzymatic browning reaction contributes to the development of desirable flavor and aroma compounds, but it also generates process contaminants. The Maillard reaction products (MRPs) include furans, pyrazines, and acrylamide, among others. The formation of acrylamide, a potentially carcinogenic compound, is a major concern in coffee roasting. The precursors for acrylamide formation are asparagine and reducing sugars, and their levels in coffee beans can vary depending on factors such as coffee variety, processing methods, and storage conditions [4].

Strecker degradation

Strecker degradation is another important pathway contributing to the formation of process contaminants during coffee roasting. This reaction involves the degradation of amino acids via the Maillard reaction, resulting in the formation of volatile compounds such as aldehydes, ketones, and sulfur compounds. Some of these compounds, such as methional and 2-furanmethanethiol, are associated with off-flavors and may impact the sensory quality of roasted coffee [5].

***Address for Correspondence:** Christopher D. Martin, Department of Agricultural, Food, Environmental and Animal Sciences, University of Udine, Udine, Italy, E-mail: m.chrisdmartin@yahoo.edu*

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Lipid oxidation

Lipid oxidation is a significant contributor to the formation of process contaminants in coffee roasting. Coffee beans contain lipids, including triglycerides and free fatty acids, which undergo oxidation during roasting. This oxidation process leads to the generation of volatile and non-volatile compounds, such as aldehydes, ketones, and hydroperoxides. Some of these compounds, including hexanal and heptanal, are associated with off-flavors and rancidity.

Degradation of chlorogenic acids

Chlorogenic Acids (CGAs) are naturally occurring phenolic compounds found in coffee beans. During coffee roasting, CGAs undergo thermal degradation, resulting in the formation of quinolones, lactones, and phenolic compounds. These compounds contribute to the sensory characteristics of roasted coffee but can also act as process contaminants. For example, 4-vinylcatechol, a degradation product of CGAs, has been identified as a potential mutagenic and carcinogenic compound.

Influence of roasting parameters

The formation of process contaminants during coffee roasting is influenced by various roasting parameters, including temperature, time, and moisture content. Higher roasting temperatures and longer roasting times tend to promote the formation of certain contaminants, such as acrylamide and furans. Additionally, moisture content plays a role in the generation of volatile compounds, as the presence of water can affect the availability of reactants and the occurrence of chemical reactions.

Identification techniques

Accurate identification and quantification of process contaminants are crucial for understanding their impact on coffee quality and safety. This section reviews various analytical techniques used to identify and measure process contaminants, including Gas Chromatography-Mass Spectrometry (GC-MS), Liquid Chromatography-Mass Spectrometry (LC-MS), and sensory analysis.

Common process contaminants in roasted coffee

In this section, the most commonly identified process contaminants in roasted coffee are discussed. It includes acrylamide, Polycyclic Aromatic Hydrocarbons (PAHs), furans, mycotoxins, and Heterocyclic Amines (HCAs). Each contaminant is described in terms of its formation, occurrence, potential health risks, and regulatory limits, if applicable.

Health implications and regulatory aspects

The safety of coffee consumption is a significant concern, and understanding the health implications of process contaminants is essential. This section discusses the potential health risks associated with the consumption of coffee contaminated with process contaminants. Additionally, it outlines the current regulatory landscape and limits set by international agencies.

Mitigation strategies

To minimize the formation of process contaminants during coffee roasting, this section highlights various mitigation strategies that coffee producers can employ. It includes the optimization of roasting parameters, green coffee selection, post-roasting processing, and the use of additives or processing aids.

Discussion

The formation mechanisms of process contaminants during coffee roasting are complex and can significantly impact the safety and quality of the final product. Understanding these mechanisms is crucial for developing strategies to mitigate the formation of contaminants and ensure the production of safe and high-quality roasted coffee. The Maillard reaction, a prominent reaction during coffee roasting, contributes to the development of desirable flavor and aroma compounds. However, it also leads to the formation of process contaminants such as acrylamide. Acrylamide is a potential carcinogen, and its presence in roasted coffee has raised concerns regarding consumer safety. Efforts to minimize acrylamide formation during coffee roasting include optimizing roasting parameters, selecting coffee varieties with lower asparagine and reducing sugar content, and employing post-roasting processing techniques [2].

Strecker degradation, a pathway that occurs alongside the Maillard reaction, can result in the generation of volatile compounds that contribute to off-flavors in roasted coffee. Managing Strecker degradation can involve controlling the availability of reactants, such as amino acids, during roasting. Understanding the impact of different amino acid profiles and roasting conditions on the formation of Strecker degradation products can help mitigate the development of undesirable flavors. Lipid oxidation is another significant contributor to the formation of process contaminants during coffee roasting. The oxidation of lipids leads to the generation of volatile and non-volatile compounds that can affect the sensory properties of coffee, such as off-flavors and rancidity. Controlling lipid oxidation can involve proper storage and handling of green coffee beans to minimize lipid degradation before roasting, as well as optimizing roasting conditions to reduce oxidative stress.

The degradation of chlorogenic acids during coffee roasting results in the formation of various compounds that contribute to the sensory characteristics of roasted coffee. However, some of these compounds may also act as process contaminants with potential health implications [6,7]. Understanding the factors influencing the degradation of chlorogenic acids and developing strategies to minimize the formation of potentially harmful degradation products can help maintain the quality and safety of roasted coffee. The influence of roasting parameters, including temperature, time, and moisture content, on the formation of process contaminants cannot be understated. Fine-tuning these parameters can significantly impact the formation of specific compounds, allowing coffee producers to optimize roasting profiles and minimize the generation of contaminants.

Future Directions and Conclusion

The review concludes with an outlook on future research directions in the field of process contaminants during coffee roasting. It emphasizes the need for continued efforts to understand the formation mechanisms, develop new analytical techniques, establish stricter regulations, and explore novel mitigation strategies to ensure the production of safe and high-quality roasted coffee. Overall, this review manuscript provides a comprehensive understanding of the formation, identification, health implications, and mitigation of process contaminants during coffee roasting. It serves as a valuable resource for researchers, coffee producers, and regulatory agencies, facilitating the development of strategies to minimize the formation of contaminants and ensure the production of safe and enjoyable coffee for consumers worldwide.

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Conflict of Interest

There is no conflict of interest by authors.

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